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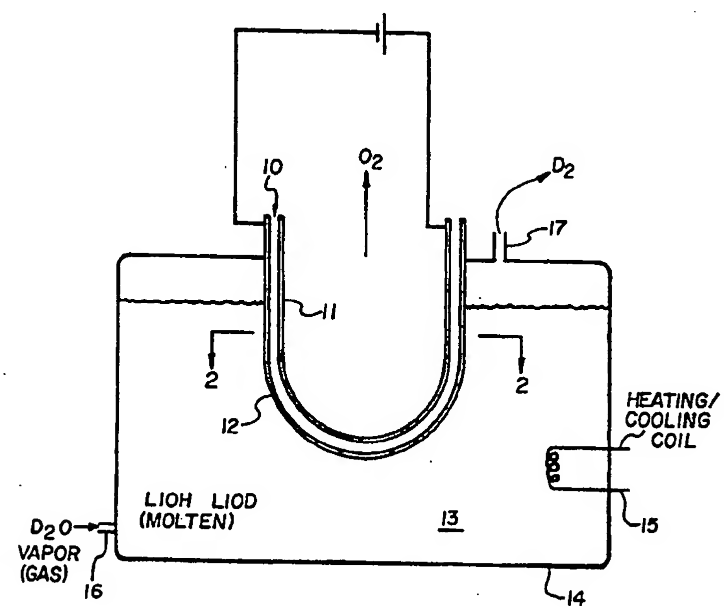
(54) Title: ELECTROLYTIC APPARATUS FOR DISASSOCIATION OF COMPOUNDS CONTAINING HYDROGEN ISOTOPES

(57) Abstract



An improved apparatus for high temperature electrolytic decomposition of compounds containing hydrogen isotopes, e.g. deuterium oxide, is disclosed. The apparatus includes a solid state electrolyte (10) capable of conducting oxygen, protons, lithium ions, or sodium ions; an anode (11) porous to oxygen adherent to one surface of the solid state electrolyte (11) and a hydrogen absorbing cathode (12) such as Fe, Ti, Mg, Ni, Pd and their alloys, adherent to another surface of the solid state electrolyte (11). The apparatus is placed in a hydrogen isotope media (13) and one to two volts of direct current passed through the electrodes (11, 12). Upon application of this voltage two D_2O molecules decompose into $2D_2$ and O_2. Oxygen evolves at the anode (11) while D_2 is absorbed in the cathode (12). Once the saturation of D_2 in cathode (12) occurs fusion begins to take place thus releasing heat energy.

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ELECTROLYTIC APPARATUS FOR DISASSOCIATION OF COMPOUNDS CONTAINING HYDROGEN ISOTOPES

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Application Serial No. 889,214, now U.S. Patent No. 4,725,346, and co-pending U.S. Application Serial No. 156,549 filed February 16, 1988, the contents of both of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field: This invention relates to energy producing devices generally and to a device for dissociating compounds containing hydrogen isotopes particularly.

State of the Art: Recent work at the University of Utah by Drs. Pons and Fleishmann has been reported as demonstrating low-temperature (room-temperature) fusion of deuterium by electrolysis of aqueous deuterium oxide in the presence of lithium hydroxide, and/or lithium oxydeuteride, as an electrolyte.

The Pons/Fleishmann experiment reportedly evidenced a release of heat energy in an amount of about four times greater than the total electrical energy input into the device. The experiment involved the use of a coiled platinum anode and a rod-like palladium cathode. The two electrodes were immersed in a bath of aqueous deuterium oxide ("heavy water") and direct current was supplied. Lithium oxydeuteride served as an electrolyte. The apparatus was run for several days. Oxygen gas was liberated at the anode and some deuterium was liberated at the cathode. Also, some deuterium was apparently captured in pores or interstices of the palladium cathode in a manner whereby pairs of deuterium atoms could evidently engage in fusion producing an abundance of heat energy.

The experimental data at this time is

insufficient to determine the number of neutrons and amount of gamma radiation released. Therefore, some question may exist as to whether or not the heat is resulting from the fusion of deuterium or from some other unexplained nuclear, physical, or chemical reaction or interaction.

The data collected by Pons and Fleishmann indicates that electrolysis of the various components does result in the production of much more energy output than energy input. Thus, regardless of the mechanism involved, the Pons/Fleishmann apparatus and process accomplishes a very useful result, namely, the production of more energy than it consumes.

The work of Fleishmann and Pons has been reported as confirmed by the Georgia Institute of Technology, Texas A & M University, and Moscow University. Texas A & M observed an amount of heat energy released far in excess of that put into the electrolytic cell while Georgia Tech observed the presence of a larger quantity of neutrons, indicating the likelihood of fusion of some of the components.

SUMMARY OF THE INVENTION

The invention includes an apparatus for the decomposition of compounds containing hydrogen isotopes. The apparatus includes: 1) hydrogen isotope media; 2) a solid electrolyte; 3) an anode adherent to one surface of the solid electrolyte; and 4) a hydrogen-absorbing cathode adherent to another surface of the solid electrolyte in contact with the hydrogen isotope media.

A compound containing a hydrogen isotope, for example, deuterium oxide, is introduced into the hydrogen isotope media, typically a molten salt bath, which bath will typically be a molten solution of lithium hydroxide or lithium oxydeuteride. A direct current is applied to the cathode and the anode. By some means, the deuterium

oxide "disassociates" into oxygen gas and deuterium gas which is absorbed into the cathode causing fusion and thus releasing energy.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of an apparatus for disassociating deuterium oxide (a "cell") utilizing a solid state electrolyte;

FIG. 2 is a cross-sectional view of a tubular solid state electrolyte with electrodes on the internal and external surfaces taken along section line 2-2 of FIG. 1;

FIG. 3 is a cross-sectional view of a tubular solid state electrolyte having internal and external electrodes wherein the tubular electrolyte acts as a container for a molten alkali metal compound;

FIG. 4 is a partial cross-sectional view of a hydrogen ion (proton) conducting electrolyte coated with appropriate electrodes on each surface;

FIG. 5 is a partial cross-sectional view of a lithium ion conducting electrolyte coated with appropriate electrodes on each surface;

FIG. 6 is a cross-sectional view of a preferred embodiment of a cell wherein the cathode is "sandwiched" between the electrolyte and anodes; and

FIG. 7 is a cross-sectional view of a preferred embodiment of the cell wherein the hydrogen absorbing cathode is in the center of the cell and a porous oxygen evolving anode surrounds the exterior of the electrolyte.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Compounds containing a hydrogen isotope as contemplated herein, are compounds which contain deuterium (d), tritium (T) or hydrogen (H). Such compounds are generally of the formula:

$$XY$$

wherein X is hydrogen, deuterium, or tritium, and Y is the remainder of the compound. Typical of such compounds are deuterium oxide (D_2O), deuterium gas (D_2), various deuteric acids (R-COOD, wherein R is an alkyl, aryl, or benzyl group) deuterium sulfide, deuterium selenide, deuterium telluride; metal deuterides (LiD), tritium oxide, water, hydrogen chloride, hydrogen sulfide, salts containing hydrogen, deuterium and/or tritium, and other compounds containing a hydrogen isotope, especially those that ionize in solution.

Hydrogen isotope media is any media which will contain a hydrogen isotope and present it for fusion. Such medium include molten salt baths, gaseous deuterium oxide, heavy water steam, etc.

One alternative hydrogen isotope media is D_2SO_4, the deuterium counterpart of sulfuric acid. In such an instance, palladium and its alloys and composites are preferred for use as the cathode, and platinum and LSM would be preferred anodes to avoid oxidation of the electrodes, sulfuric acid may be admixed with the D_2SO_4. The resultant low pH (1.0 to 4.0) may speed up the reaction due to an increased hydrogen isotope ion concentration and increased conductivity of the hydrogen isotope media.

Deuterium oxide ("heavy water") is readily commercially available from Fischer Scientific and Isotech of Ohio. It is a preferred compound for use in the invention since it is readily available, contains a preferred hydrogen isotope, i.e. deuterium, and can also act as its own hydrogen isotope media.

The apparatus ("cell") for high-temperature electrolytic decomposition of deuterium oxide utilizing a palladium cathode in a fused alkali metal hydroxide or oxydeuteride bath includes a solid state electrolyte capable of transporting oxygen ions under the influence of a direct current. The solid state electrolyte should

be capable of withstanding temperatures well in excess of 300°C and preferably temperatures in the range of 200° to 800°C.. On one surface of the electrolyte is placed an anode which is generally a coating of electro-conductive material which is porous or pervious to oxygen.

On an opposed surface of the electrolyte is a cathode, preferably of palladium, which is porous to deuterium oxide molecules. A non-porous cathode composed of palladium and a proton transporting material such as barium ceriate ($BaCeO_3$), hydrogen uranyl phosphate ($HUO_2 \cdot PO_4 \cdot 4H_2O$) or the like, may be used. The proton transporting material also transports water and D_2O. The fused alkali metal hydroxide or oxydeuteride is in contact with the hydrogen-absorbing cathode.

If the electrolyte is in tubular form, for example a tube of zirconia or ceria having a closed end and an open end (e.g. FIG. 1), and the palladium cathode is coated on the outside of the tubular electrolyte, then the tube is immersed in a bath of molten alkali metal hydroxide or oxydeuteride. If the hydrogen absorbing cathode is on the inside of the tube, then the alkali metal hydroxide may be contained within the tube (FIG. 3).

Electrical leads are provided to the cathode and anode in order that a direct current may be imposed upon them to create a potential difference across the electrolyte. Also, means for heating is provided to first melt the alkali metal hydroxide or oxydeuteride and to maintain the molten alkali metal hydroxide at an appropriate temperature. If heat or energy is given off by the device, then the heating means may preferably be converted to cooling means so as to maintain the temperature of the molten alkali metal hydroxide or oxydeuteride below its boiling point.

Further description of the invention may be facilitated by reference to FIG. 1. FIG. 1 is a cross-

sectional, elevational view of one embodiment of the instant invention. In this embodiment, a zirconia tube 10 having an anode coating 11 on its interior and a cathode 12 of palladium coated on its external surfaces, is immersed in a fused lithium hydroxide (LiOH) and/or lithium oxydeuteride (LiOD) bath 13 ("bath"). The electrolyte bath is contained within a suitable container 14 for containing a high temperature bath, for example, an alumina or zirconia ceramic.

A hollow, tube-like heating coil/cooling coil 15 is also provided to alter the temperature of the bath as necessary. A material of choice for use as the hollow tube heating/cooling coil would be LSM. During the heating phase the coil may have a very hot liquid or very hot gas passing through it. For example, liquid sodium or superheated steam may be used to heat the alkali metal bath. During the cooling phase, a cooler liquid or gas may be passed through the coil 15. For example, molten sodium of a lower temperature than the bath may be passed through the coil. Also, water may be passed through the coil as a means of cooling the bath 15 whenever heat energy is given off by the apparatus. This heated fluid may then be used for whatever purpose desired (e.g. generation of steam).

Inlet means 16 in communication with the bath 13 is provided for the introduction of deuterium oxide vapor and an aperture or other vent means 17 is provided to permit venting of deuterium or other fluids from the device. Oxygen gas vents from the open end of the zirconia tube (see FIG. 1).

As illustrated in FIG. 1, the external electrode 12 is a porous cathode and the internal electrode 11 is an anode. A direct current power source is applied to the two electrodes. One to two volts are preferably passed through the apparatus. Standard electrical sources may be used, such as a dry cell. When

deuterium oxide gas is introduced into the bath 13, for example through the inlet means 16, the deuterium oxide will ultimately reach an equilibrium concentration in the molten lithium hydroxide and/or lithium oxydeuteride.

Upon the application of direct current to the apparatus, a reaction takes place at the cathode/electrolyte interface. The porous cathode permits deuterium oxide (heavy water) molecules to disassociate at that interface into oxygen ions and deuterium ions. The oxygen ions will be transported through the electrolyte 10 to the anode where dissociated oxygen ions will combine to form an oxygen molecule (O_2). The oxygen molecules then pass through the anode and are released from the interior of the electrolyte tube.

A deuterium ion at the cathode/electrolyte interface will, to a large extent, pass back out through the pores of the electrolyte into the palladium cathodes and combine with another deuterium ion to form a deuterium molecule as the ions pick up electrons from the cathode. However, according to the model of Pons and Fleishmann, a certain percentage of the deuterium ions might be captured within the palladium cathode and, at some point fuse or interact with other materials to create a source of energy. For example, it has been postulated that some fusion of hydrogen and lithium may also occur.

In FIG. 2, a cross-sectional view of the coated electrolyte tube 10 along section lines 2-2 of FIG. 1 is illustrated. The cathode coating 12 is a continuous coating covering the entire external surface of the electrolyte 10 so that all that portion of the electrolyte which is submerged in the molten alkali metal hydroxide or oxydeuteride bath 13 is coated with the cathode. The electrode must be sufficiently porous that heavy water molecules may pass through the electrode to be present at the cathode/electrolyte interface. The

thickness of the cathode coating, which in the depicted embodiment is palladium, may vary from about 0.05 to about 2.0 millimeters (mm).

The electrolyte illustrated in FIG. 1 is tubular in shape, having a closed end and an open end. Other shapes of electrolytes may be used, for example, the electrolyte may be a tubular member having two open ends where each end is sealed to the container used to hold the fused salt. The electrolyte may also be a flat electrolyte which forms one wall of the molten hydroxide container.

The electrolyte of FIG. 1 which is illustrated in cross-section in FIG. 2 is tubular and thus has a circular cross-section. The electrolyte is preferably Y_2O_3 doped ceria, zirconia, hafnia, thoria, or bismuth oxide. These chemicals in relatively pure form are all readily available from Ceramatec, Inc. of Salt Lake City, Utah.

Ceramic forming techniques to form an electrolyte tube of ceria are well known to those skilled in the art. For example, ceria powder is first shaped into a tubular form, then isostatically pressed and sintered at 1550°C for four hours. Before sintering, a slurry of each electrode, for example, palladium filings along with an organic binder and a solvent, may be brushed onto the particular surfaces of the isostatically pressed electrolyte. The electrolyte along with the adherent electrodes may then be co-sintered to from the electrolyte in combination with the anode and cathode. The thickness of the electrolyte may vary considerably, although it is preferably from about 0.05 to about 2.0 mm.

On the internal surface of the electrolyte is an anode coating. The anode must be pervious or porous to oxygen molecules. Examples of materials suitable for use as an anode include molybdenum and titanium nitride.

Oxygen ions passing through the electrolyte will upon reaching the anode give up electrons and combine to form an oxygen molecule. The oxygen molecule then passes through the anode coating to rise through the tube member to be released. Naturally, the oxygen may be captured and used for various purposes. One advantage of the instant invention is that the oxygen emitted from the system is very dry and very pure.

In FIG. 3, another embodiment of the invention is illustrated wherein an electrolyte tube 19 acts as a container for the fused hydroxide. In the embodiment illustrated in FIG. 3, a cathode of palladium 18 is coated onto the interior surface of the electrolyte 19 the anode 20 is present on the external surface of the closed end tube. Inlet means for deuterium oxide 21 is placed within the molten alkali metal hydroxide bath 22. Preferably, the deuterium oxide inlet 21 is an elongated tubular member which reaches close to the bottom of the electrolyte tube so that the deuterium oxide may be readily dispersed throughout the fused hydroxide.

In the embodiment of FIG. 3, oxygen will be admitted on the external surface of the anode 20 while deuterium, at least to some extent, will be released in the interior of the electrolyte 19.

A heating element may be disposed within the interior of the electrolyte of FIG. 3 (not shown). The heating element preferably doubles as a cooling element in the event of heat generation within the apparatus. Alternatively, the tube may be immersed in a liquid or gas bath or stream to heat or cool the external surface of the electrolyte as necessary.

A large plurality of the tubes may be utilized in conjunction with one another and may, for example, be contained within a single heating/cooling stream or fluid.

The electrolytes utilized in the instant invention may be ceramic oxides such as zirconium oxide (zirconia), hafnium oxide (hafnia), bismuth oxide, mullite, thorium oxide (thoria), cerium oxide or a combination of these compounds. Other compounds which may be useful as electrolytes in the invention include $BaCeO_3$ or $SrCeO_3$ or proton conductors.

Anode materials may be a ceramic oxide material such as lanthanum strontium manganate (LSM) or noble metals such as platinum, palladium, or gold. Also, other oxides such as niobium or tantalum doped titanium oxide (available from Ceramatec, Inc. of Salt Lake City, Utah) or $SrCo_{0.8}Fe_{0.2}O_3$ may be used. These anode materials must be porous to permit oxygen molecules to pass through them. Silver, which is pervious to oxygen ions, may be advantageously used in a non-porous form.

The cathode material of choice in this instance is palladium, since this is the material that has been found by Drs. Pons and Fleishmann to have certain desirable characteristics in causing heat generation from electrolysis of heavy water. Other useful cathode materials include titanium, nickel alloys, and iron-titanium alloys since these, like palladium, have enormous hydrogen absorption capabilities. Other cathode materials include composites of various protonic conductors (see Table I) mixed with hydrogen absorbing materials such as Fe, Pd, Ti, Mg, Nickel and their alloys.

A composite of alkali metal deuteride and a hydrogen absorbing cathode are especially preferred cathodes for use in a cell. These composite best when used with corresponding alkali metal ion conductors, such as those listed in Table I. (e.g. lithium deuteride and LiF doped with CaF_2 or sodium deuteride and NaBeta alumina).

The cathode may also preferably be a composite of palladium and proton conductor. Such a device would more readily being the disassociation reaction sooner. Alternatively the cathode may contain pore-forming materials such as Avicel or carbon fibers.

The temperature of operation is generally above the melting point of the bath and below its boiling point. A preferred temperature is typically in the range of 200 to 600°C.. Table I shows various temperature ranges dependent on the choice of conductor used as an electrolyte.

TABLE I

ELECTROLYTE	RECOMMENDED TEMP (°C)
A. Proton conductors	
$HUO_2 \cdot PO_4 \cdot 4H_2O$	0-100°
NH_4NbWO_6	100-500°
NH_4TaWO_6	100-500°
$H_2AlP_3O_{10}$	100-300°
Ni^3 doped $KTiO_3$	300-500°
$SrCeO_3$ (doped with Y)	300-900°
$BaCeO_3$ (doped with Y)	300-900°
NH_4^+/H_3O^+ BETA ALUMINA	20°-150°
B. Lithium ion conductors	
$(Li_2SO_4)_{0.77}(Ag_2SO_4)_{0.33}$	300-700°
Li Al_2O_3 ($X=I_1Br_1Cl$)	100-500°
LiF doped with CaF_2	300-800°
Solid state polymer lithium electrolytes such as	
$(PEO)_8$ $LiCF_3SO_3$ Polystyre	0-150°C
(PEO) - $LiClO_4$	70-200°C

C. Sodium ion conductors

Na Beta Alumina	25-1000°
NaSiCON ($Na_{2.94}Zr_{1.49}P_{0.8}Si_{2.2}O_{10.85}$)	100-600°
NaBr, NaI, NaF and mixtures thereof.	100-800°

D. Polymer based solid electrolytes having high ionic conductivity in presence of water.

NAFION (Dupont Brand)	20-150°

E. Oxide ion conductors solid electrolyte

Stabilized ZrO_2, CeO_2, HfO_2, ThO_2	400-1000°
Stabilized Bi_2O_3	300-700°
PerouskTe mixed oxygen conductors such as	
$La_{1-x}Sr_xCo_{1-x}Fey O_3^{-d}$	400-1000°

The deuterium oxide may be replaced partly, or wholly, by tritium oxide. Tritium is generally more susceptible to fusion and generally releases more neutrons and more energy upon fusion.

Another variation of an electrolytic apparatus to disassociate deuterium oxide, or in the alternative, to disassociate deuterium compounds is illustrated in FIG. 4.

FIG. 4 is a partial cross-sectional view of a solid state electrolyte, preferably a ceramic electrolyte, which is a proton, i.e. hydrogen ion (deuterium ion) conductor. Suitable electrolytes 22 for this purpose include barium ceriate ($BaCeO_3$), strontium ceriate ($SrCeO_3$), rubidium tantalum tungstate ($RbTaWO_3$) or hydrogen uranyl phosphate. Suitable temperatures of operation of such electrolytes varies from about 20°C to about 900°C. depending on the solid electrolyte.

The electrolyte of FIG. 4 may be substituted in an apparatus such as that illustrated in FIGS. 1 or 3.

In the apparatus of FIG. 4 any suitable anode 20 material such as platinum, LSM ($LaSrMnO_3$), silver, gold or the like may be used. The anode material adheres to the electrolyte and is porous to deuterium oxide, as the case may be.

The cathode 18 material is preferably palladium, although titanium or titanium-iron alloys may be used.

When D_2O is in contact with the anode of FIG. 4, the anode must be sufficiently porous to allow D_2O to be present at the anode-electrolyte surface. Application of a direct current to the electrodes causes the disassociation of D_2O at the anode-electrolyte surface, releasing 2 D^+ ions for the transport through the electrolyte to be captured by the palladium electrode. In the embodiment depicted in FIG. 4, the cathode 18 need not be porous, although it may be.

Disassociation of D_2O also releases oxygen, wherein two oxygen ions (2 $O^=$) give up four electrons to the circuit and combine to form O_2 gas. The O_2 gas passes through the porous anode and is vented from the system as depicted in FIG. 4.

Palladium is known to capture (absorb) about 900 times its volume of hydrogen. Thus, the apparatus could be operated for long periods of time with non-porous palladium cathodes before its deuterium absorption ability would be diminished.

An apparatus such as that illustrated in FIGS. 1 or 3 and, employing a proton-conducting electrolyte, may be used to disassociate D_2O into 2 D^+ ions (deuterium ions) which are conducted from the anode-electrolyte surface, through the electrolyte and into the palladium cathode. Fusion, to the extent it occurs in the cathode, may do so from the fusing of two deuterium ions or two

deuterium molecules (D_2). Some of the deuterium ions (D^+) undoubtedly pick up electrons and convert to D_2.

Another variation of an electrolytic apparatus for the release of deuterium is illustrated in FIG. 5. In this embodiment, alkali metal oxydeuteride may be disassociated in the presence of an alkali metal ion-conducting electrolyte 19 such as NaSiCON ($Na_{2.94}Zr_{1.49}P_{0.8}Si_{2.2}O_{10.85}$), a sodium ion conductor which is stable in the presence of water. This type of electrolyte 19 may be made as a lithium ion conductor such as mentioned in Table I. The electrolyte of FIG. 5 may be used in an apparatus of the type illustrated in FIGS. 1 or 3. A porous palladium cathode 18 is adherent to one surface of the electrolyte. The cathode 18 is porous to lithium oxydeuteride so that it may be present at the cathode-electrolyte interface to disassociate at the cathode according to the following reaction:

$$2\ Li^+ + 2D_2O \xrightarrow{+2e-} 2\ LiOD + D_2$$

at the anode 20 which may be made of molybdenum electrode or TiN:

$$2\ LiOD \xrightarrow{-2e-} 2\ Li + D_2O + O\uparrow$$

for a total reaction:

$$2D_2O \longrightarrow 2D_2\ (cathode) + O\ (anode)$$

and at the cathode:

$$D_2 \longrightarrow fusion \longrightarrow energy$$

In the above reaction, Li^+ ions are conducted through the electrolyte to combine at the cathode-electrolyte surface by combining with an electron to form lithium.

Numerous cells may be used in series to take advantage of high voltage, low current power sources readily available throughout the world. In the case of

an alternating current, a rectifier can be used to convert the alternating current into a direct current. The cells are connected in series with the amount of voltage (e.g. 110V) being divided by the number of volts desired per cell (e.g. 1-2V) to determine the number of cell needed.

Steam generated through the use of the cooling coils associated with the cells can be collected to generate more electricity or to other useful work.

The cell depicted in FIG. 6 includes a hydrogen absorbing cathode 24, e.g. palladium, sandwiched by electrolyte 26 and the same or different electrolyte 28 and two anodes 30, 32 which may be also made from the same or different material. This portion of the cell is surrounded by a fluid 34 which comprises the hydrogen isotope media. This fluid may be the aforementioned molten LiOH/LiOD; gaseous D_2O, or other fluid media within which compounds containing hydrogen isotopes dissolve (e.g. aqueous Li)D or NaOD). The container 36 contains the fluid and aforementioned portions of the cell. When the compound containing a hydrogen isotope is heavy water, D_2 and O_2 evolve as depicted.

FIG. 7 depicts another preferred cell for use in the invention. In the embodiment depicted in FIG. 7, hydrogen absorbing cathode 24 contacts and is surrounded by a solid electrolyte 26. Anode 30 adheres to the outer surface of the electrolyte 26. This embodiment of the invention is particularly suited for the decomposition of gaseous D_2O which may be introduced through inlet 38. The container 36 must be able to withstand the pressures generated by gaseous D_2O at temperatures contemplated by the invention.

The particular advantages of the cells depicted in FIGS. 6 & 7 are to ensure that deuterium, and other hydrogen isotope, atoms do not pass right through the hot palladium (typically greater than (400°C) which might

dampen the fusion reactions.

Other advantages of the system using solid electrolytes include (1) solid electrolytes allow the cells to be used in higher temperature environments, plating or coating of the electrolytes, 2) allows the use of smaller amounts of relatively rare metals at the electrodes, 3) the allowance of higher temperatures creates the possibility of co-generation of electricity where temperatures must generally exceed 400°C; 4) the use of higher temperatures increases the reaction Kinetics of the system and therefore the hydrogen absorbing cathode will be more quickly saturated and able to produce heat; and 5) use of composite allows for better proton conduction and quicker reaction times.

EXAMPLE I

A preferred embodiment of the invention includes a molten salt bath of fused lithium hydroxide and lithium oxydeuteride. The solid oxygen transporting high-temperature electrolyte is cubic zirconia. The electrolyte is in a form where one side or surface of the electrolyte is coated with an electrode material which is porous or pervious to oxygen and may become an anode upon application of proper current. The anode preferably LSM, is not in contact with the fused salt. On the other surface of the solid electrolyte is a cathode formed of palladium. A container for the fused salt of the molten salt bath is provided and means to introduce a flow of deuterium oxide into the fused salt is also provided. Means to allow oxygen to exit from the anode side of the electrolyte and means to allow deuterium or hydrogen to exit from the fused salt are also present.

EXAMPLE II

Composite of LiD and Palladium

The method of making this composite involves mixing the powders of LiD and Pd together intimately and milling these powders in a ball mill for 6 to 12 hrs. under inert atmosphere. After milling, the powder mixture is pressed into slugs and then granulated to required particle size. The granulated powder is then pressed to required shape for use as cathode in solid electrolyte electrochemical cells. In some cases even sintering at 600°C is recommended for achieving higher density.

Reference herein to specific details or embodiments is not intended to limit the scope of the appended claims which define the invention.

Claims

What is claimed:

1. An apparatus for high-temperature electrolytic decomposition of compounds containing hydrogen isotopes in the presence of a hydrogen absorbing cathode and a hydrogen isotope media comprising:

a solid state electrolyte capable of transporting oxygen, protons, sodium ions or lithium ions under the influence of a direct current;

anode on one surface of said electrolyte, said anode being porous or pervious to oxygen;

a cathode of palladium, said cathode being either porous or solid or composite of proton conducting material, as the case may be;

means for directing current through said anode and cathode.

2. The apparatus of Claim 1 wherein said solid state electrolyte is made of a material selected from the group consisting of zirconia, hafnia, bismuth oxide, mullite, thoria, cerium oxide, barium ceriate; strontium ceriate, sodium beta alumina, rubidium tantalum tungstate, lithium fluoride; NaSiCON; LiSiCON and $HUO_2PO_4 \cdot 4H_2O$.

3. The apparatus of Claim 2 wherein said anode is made of a material selected from the group consisting of platinum, silver, gold, lanthanum strontium manganate, doped titanium oxide, and composites of these materials.

4. An apparatus for high temperature electrolytic decomposition of a compound containing a hydrogen isotope in the presence of a cathode and a hydrogen isotope media comprising:

a tube having a closed end and an open end and an inner and outer wall, said tube made of an electrolytic material selected from the group consisting of ceria, zirconia, hafnia, thoria, and bismuth oxide, said electrolytic material capable of transporting oxygen ions when subjected to a direct current;

an anode adherent to at least a portion of a wall of said tube;

a cathode capable of absorbing hydrogen on some portion of the other wall of said tube;

means for containing a hydrogen isotope media in contact with said anode or said cathode;

means for introducing deuterium oxide into said hydrogen isotope media; and

means for applying a direct current to the cathode and anode to create a voltage potential between said anode and cathode.

5. The apparatus of Claim 4 wherein said hydrogen isotope media is a molten alkali metal hydroxide or oxydeuteride bath and further including means for alternating heating and cooling said molten alkali metal hydroxide or oxydeuteride bath.

6. The apparatus of Claim 5 wherein said anode is made of a material selected from the group consisting of platinum, silver, gold, lanthanum strontium manganate, and doped titanium oxide.

7. The apparatus of Claim 6 wherein the cathode is made of a material selected from the groups consisting of palladium, titanium, titanium alloys, nickel, nickel alloys, iron and composites thereof.

8. The apparatus of Claim 7 wherein said cathode is a composite of hydrogen absorbing material and alkali earth metal deuteride and the electrolyte is a conductor capable of conducting ions of the alkali earth metal.

9. A process for high temperature electrolytic promotion of fusion conditions of deuterium in a palladium cathode comprising:
introducing deuterium into a bath of alkali metal hydroxide or oxydeuteride;
creating a direct current in said bath between an anode and the palladium cathode;
heating said alkali metal to melt the alkali metal hydroxide or oxydeuteride and to maintain the molten alkali metal hydroxide or oxydeuteride above its melting point until fusion of the deuterium occurs;
extracting heat from said bath after fusion occurs to maintain the molten alkali deuterium below its boiling point.

10. The process of Claim 9 wherein said molten alkali metal is lithium hydroxide.

11. The process of Claim 9 wherein said molten alkali metal is lithium oxydeuteride.

12. The process of Claim 9 wherein said molten alkali metal is an admixture of lithium hydroxide and lithium oxydeuteride.

13. The process of Claim 10 wherein said anode is made from a material selected from the group consisting of platinum, silver, gold, lanthanum strontium manganate, and doped titanium oxide.

14. The process of Claim 9 wherein said bath is heated by passing a fluid having a temperature greater than that of the melting point of the alkali metal through a hollow coil present in said bath.

15. The process of claim 14 wherein said heat is extracted from said bath of molten alkali metal by passing a fluid having a temperature less than that of the boiling point of the alkali metal through the hollow coil.

16. The process of Claim 15 further including using the heat extracted from the bath for another useful purpose.

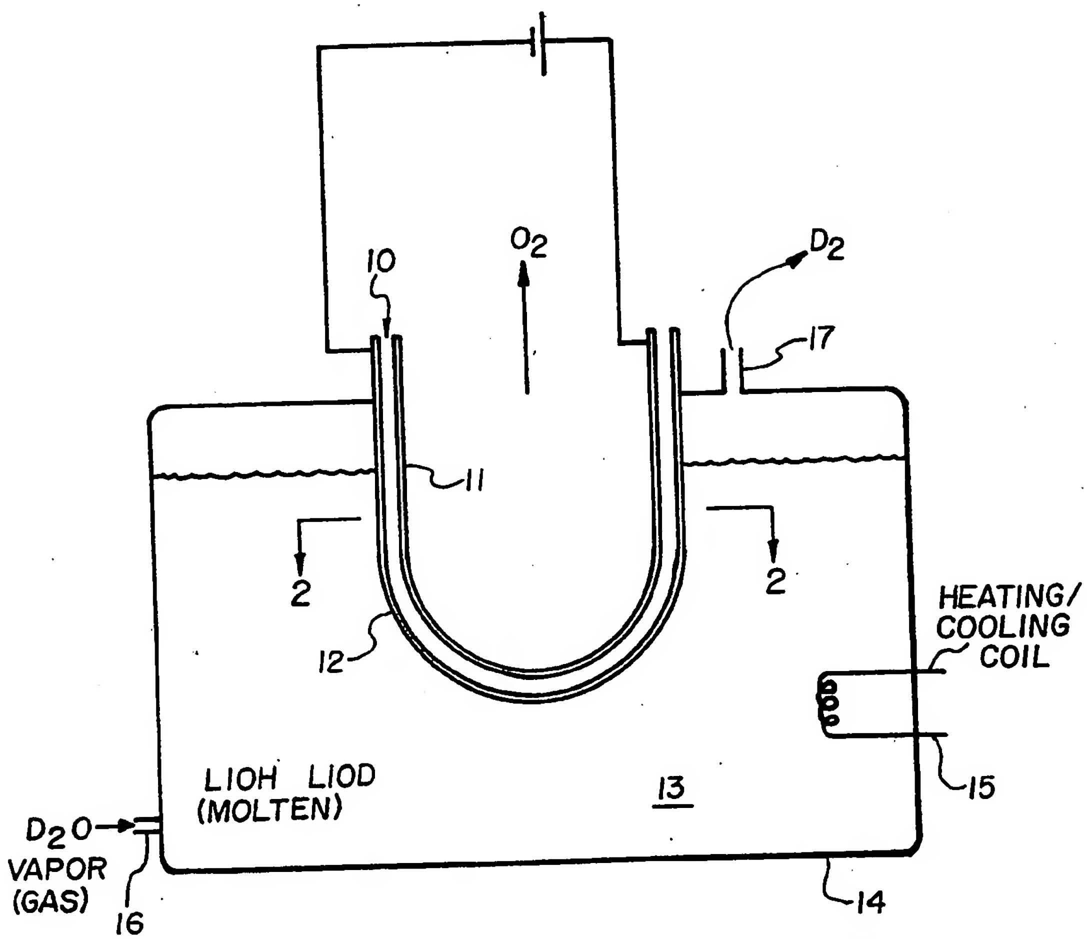
O_2
D_2
10
17
11
2
2
HEATING/
COOLING
COIL
12
LIOH LIOD
(MOLTEN)
13
15
D_2O
VAPOR
(GAS)
16
14

Fig. 1

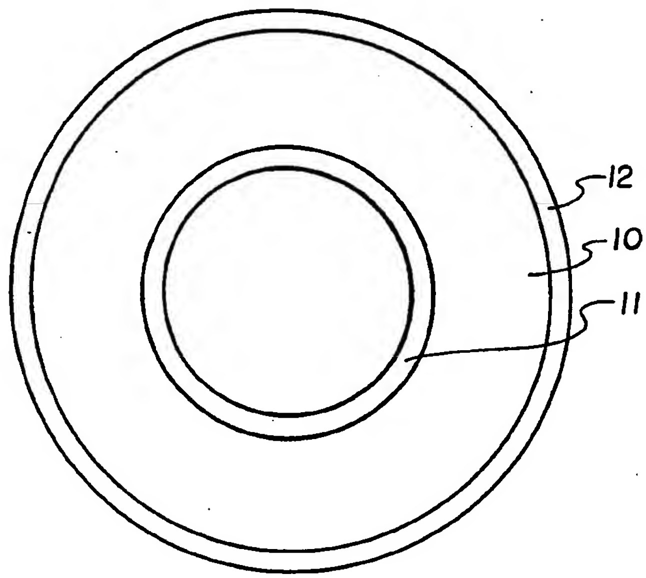

Fig. 2

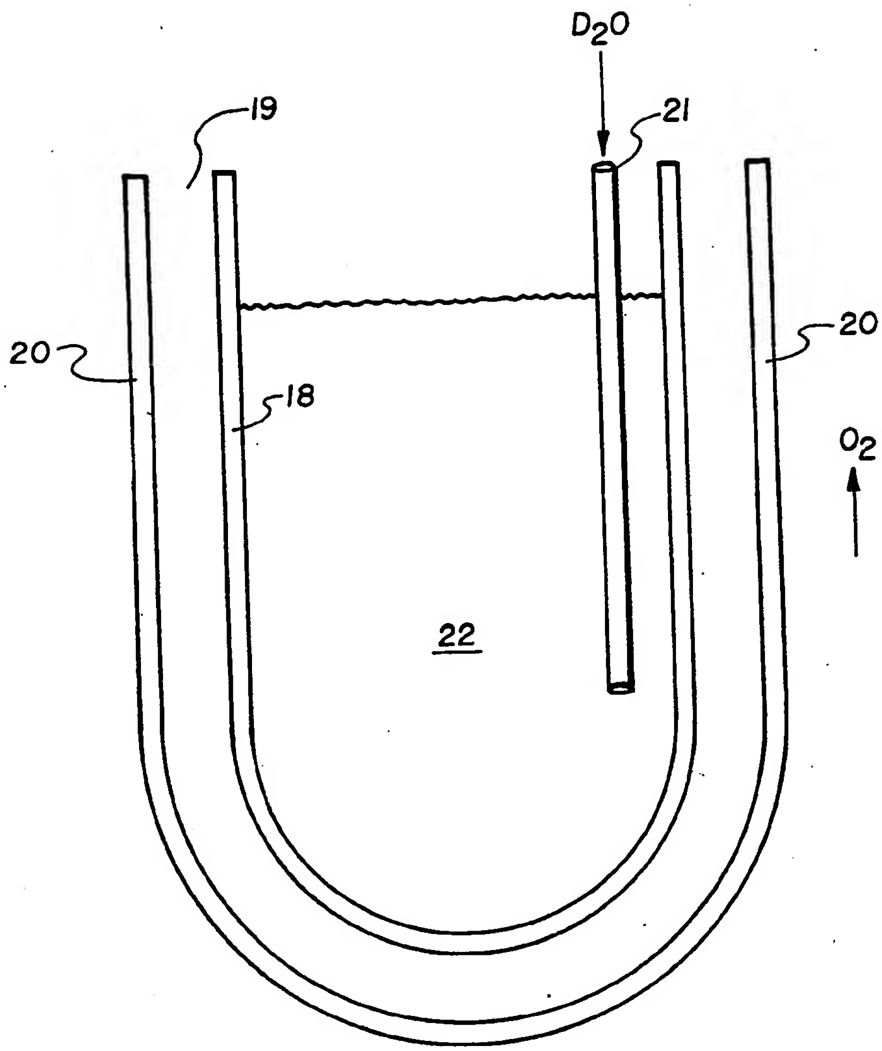

Fig. 3

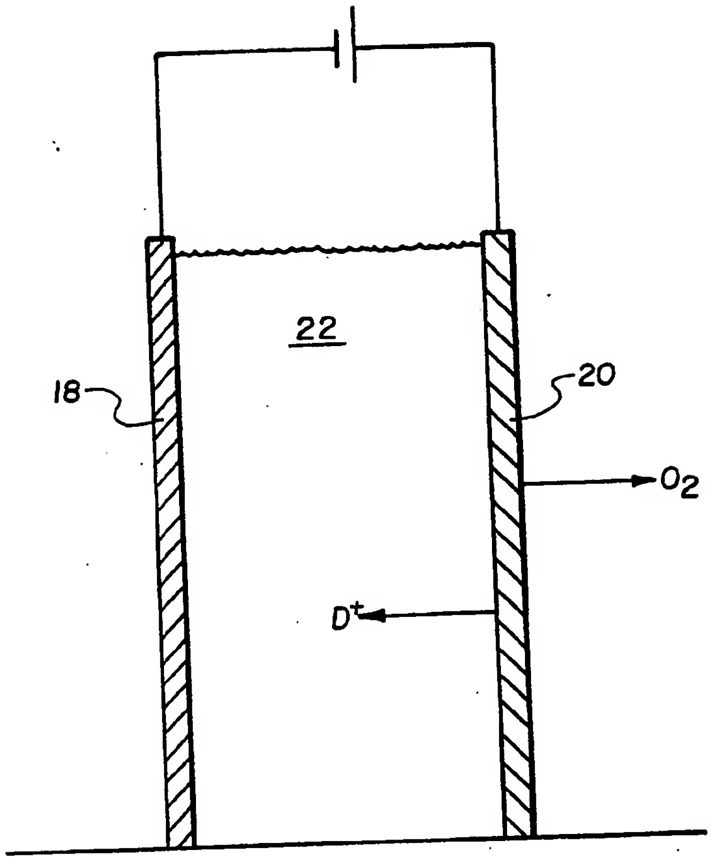

Fig. 4

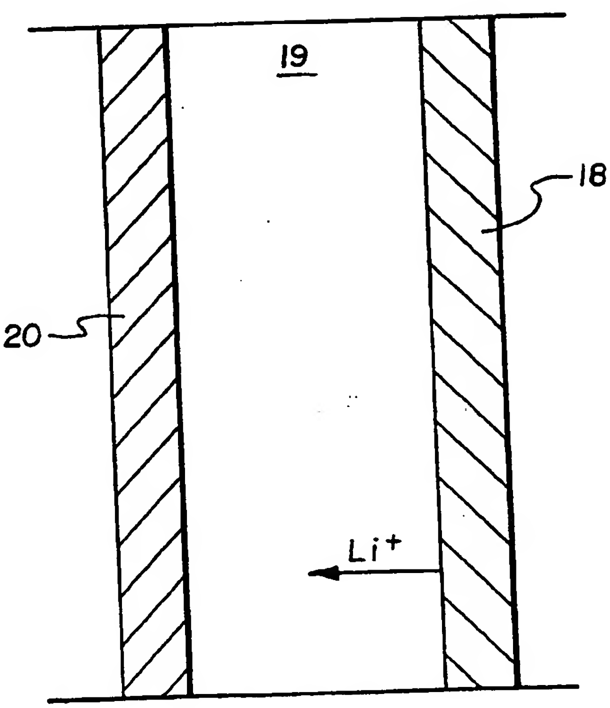

Fig. 5

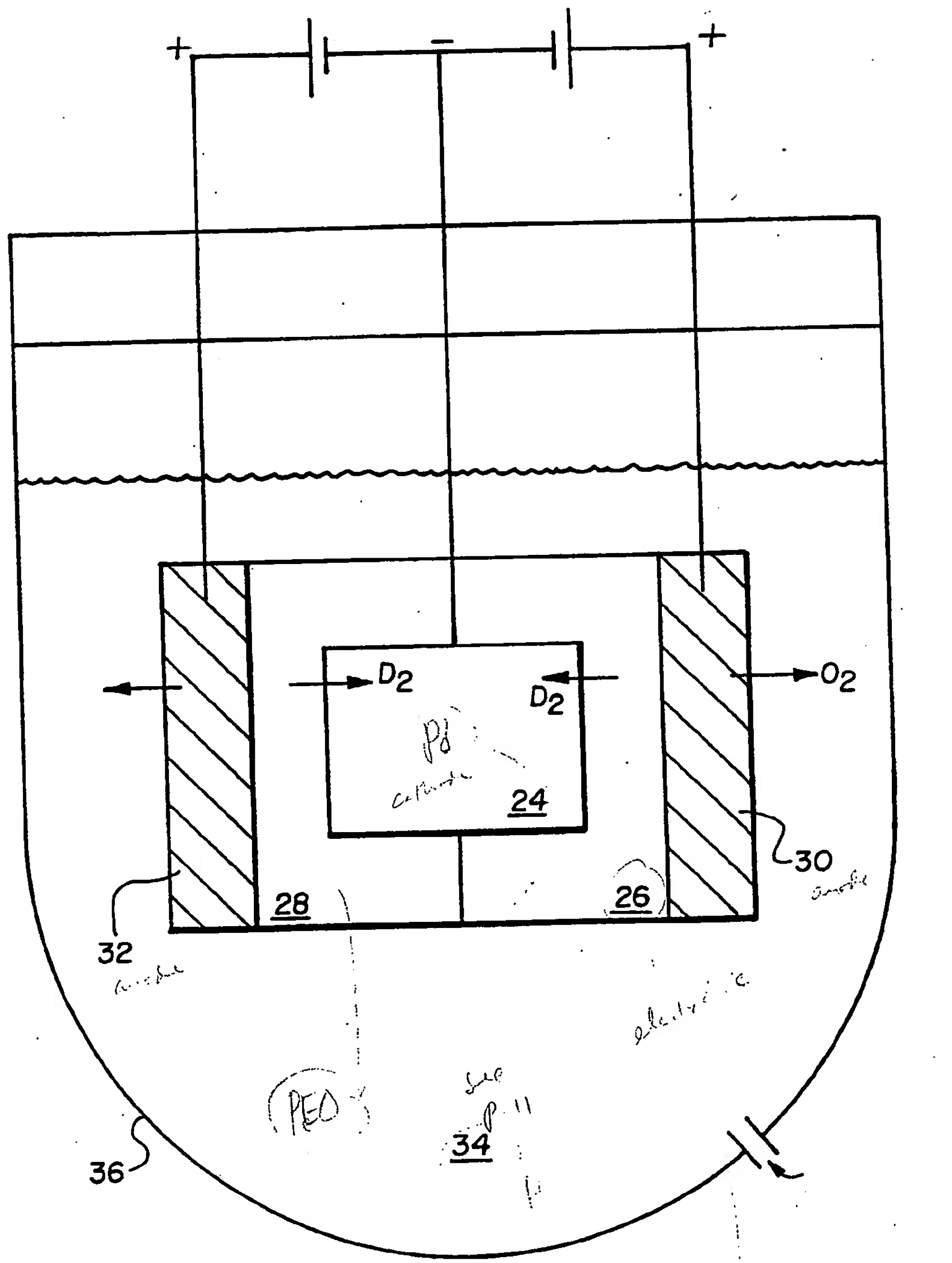

Fig. 6

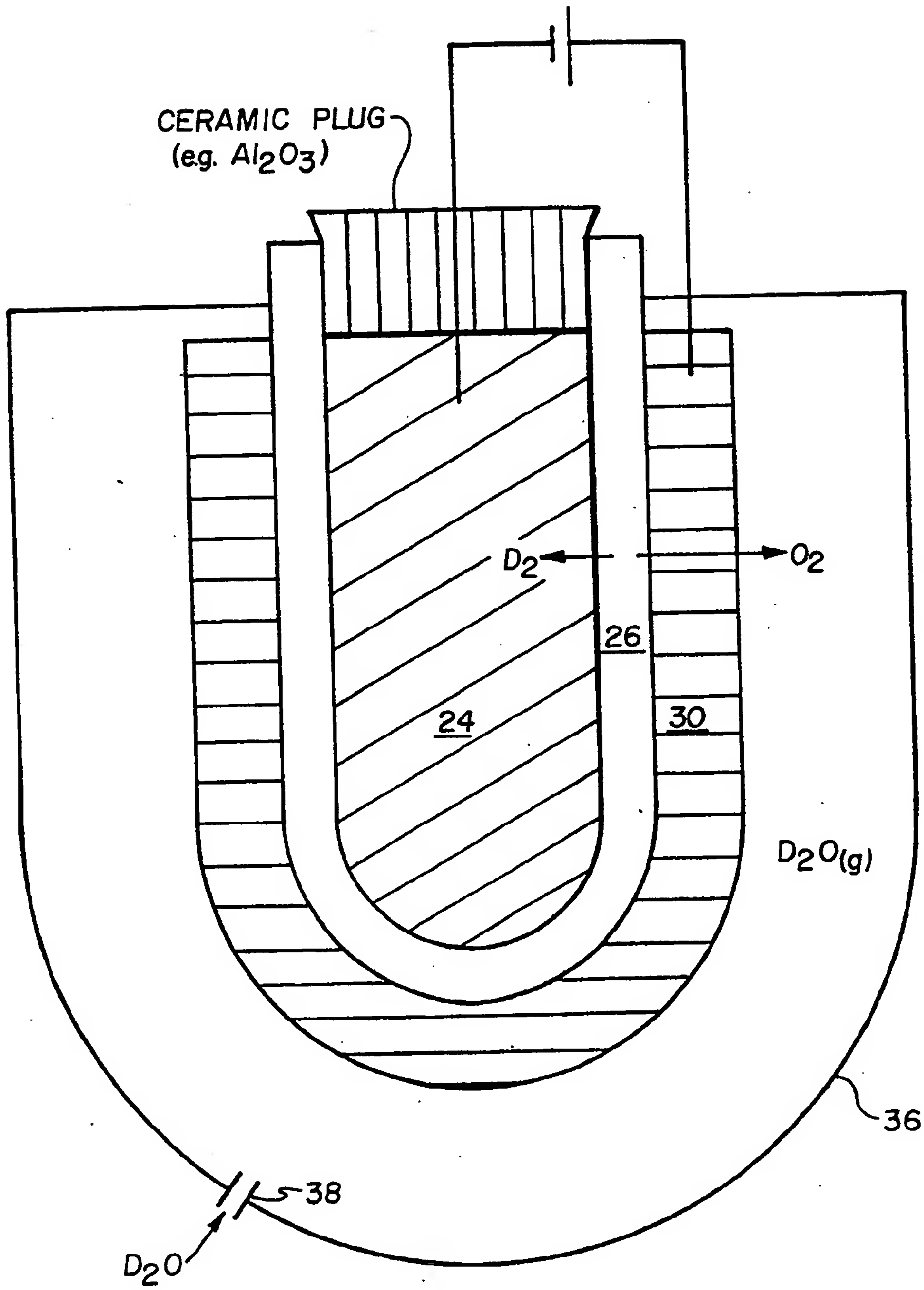

Fig. 7

INTERNATIONAL SEARCH REPORT

International Application PCT/US90/02112

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G21B 1/00; C25B 1/02, 9/00
U.S. CL: 376/100, 146

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	376/100,146; 204/60,61,129,242,243R,252; 204/262,274

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	US, A, 4,311,569 (DEMPSEY et al) 19 January 1982, See Fig. 1, cols. 2, 4-8, 10.	1-16
Y	US, A, 4,725,346 (JOSHI) 16 February 1988 See Fig. 3, cols. 1-4.	1-8
Y	US, A, 4,545,886 (NORA et al) 08 October 1985 See col. 7 lines 49+, col. 8.	1-8
Y	Journal of Electroanalytical Chemistry, Vol. 261, issued 10 April 1989, pages 301-308, FLEISCHMANN et al.	1-16
A	US, A, 4,804,448 (SAMMELLS et al) 14 February 1989 See col. 3, lines 33+.	1-8
L	Nature, Vol. 344, issued 29 March 1990, SALAMON et al, pages 401-405, cited as casting doubt on the obtainment of electrochemically induced nuclear fusion.	1-16
L	ORNL/FTR-3341, dated 31 July 1989, COOKE, see pages 3-5, cited as casting doubt on the obtainment of electrochemically induced nuclear fusion.	1-16
Y	US, A, 3,835,019 (LOVELOCK) 10 September 1974 See the abstract and col. 4 lines 65+, col. 5.	1-16
	(continued)	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
10 JULY 1990	02 AUG 1990
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Veronica Ensor for HARVEY E. BEHREND

Form PCT/ISA/210 (second sheet) (Rev.11-87)

III. DOCUMENTS CON :RED TO BE RELEVANT (CONTINUED FROM THE SE ND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	Solid State Ionics 28-30 (1988) pages 1078-1083, Deublein et al.	1-16
Y	US, A, 4,042,482 (SHANNON et al) 16 August 1977 see cols. 1, 5.	1-8
Y	US, A, 4,097,345 (SHANNON) 27 June 1978 see the abstract.	1-8
Y	US, A, 4,547,277 (LAWLESS) 15 October 1985 see the abstract.	1-7
Y	US, A, 4,670,113 (LEWIS) 02 June 1987 see fig. 1 and col. 3, lines 60+.	9-16